spaces previously isolated by railroad tracks.

REBUILDING BY DESIGN

To tackle the food insecurity that plagued New Orleans before Katrina (a challenge that continues there and in many communities across the nation), one enterprising resident turned empty lots in the devastated Lower Ninth Ward, recognized as a food desert by the US Department of Agriculture, into community orchards. Through a new nonprofit organization, these rejuvenated lots provide healthy food to residents who need it, teach people to grow their own produce, and serve as a source of community unity and pride.

Events like Katrina provide a unique opening for innovation and creativity in building communities that are both healthier and more socially vibrant than they were before disaster struck. Indeed, after Superstorm Sandy devastated communities along the East Coast, the groundbreaking Rebuild by Design contest called on innovators and experts across sectors to work with community members to envision, design, and build solutions to the region's most complex challenges. Attention to community factors that affect health figured significantly in those solutions.

Today, less than a month after Harvey, Irma, and Maria delivered back-to-back blows, funding and resources are coming into communities in Texas, Florida, and Puerto Rico. Amid the flurry of first response and the outpouring of compassion and support from across the nation and the world, we hope affected communities will capitalize fully on the rebuilding opportunities before them by using the funds and resources strategically. The blueprint should not be the status quo; it should be a vision for an infrastructure that also supports optimal health and resilience for every community.

REBUILD OUR COMMUNITIES AS WE WANT THEM

Far too many communities in the United States are suboptimally healthy and lack adequate health-supporting infrastructure, such as housing, high-quality health care, strong networks that prevent social isolation, and easy access to healthy, affordable food. Although no one wishes a disaster on any community, we know that, inevitably, they will continue to occur—and with them will come opportunity. As the famous saying goes: "Never let a serious crisis go to waste." When planning for disasters, we should also plan for what we want our communities to look like as they recover—including careful consideration of what will promote and sustain good health.

Political leaders, health officials, preparedness and response professionals, and community organizations should act now to develop a shared vision of optimal health for their community. A long-term plan for health and resilience should be a forethought, rather than an afterthought, when a disaster occurs. A detailed framework to support this kind of planning was recommended in a 2015 consensus report from the Institute of Medicine (now the National Academy of Medicine), and resources are available through the federal government's National Disaster Preparedness Framework (https://www.nap.edu/read/18996/chapter/1; https://www.fema.gov/national-disaster-recovery-framework).

As Harvey and Irma focus our national consciousness on the deadly impact of natural disasters, each of us should consider what can be done to make our communities safer, healthier, and more resilient places to live. AJPH

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Climate Change, Hurricanes, and Health

See also Zolnikov, p. 27; Lichtveld, p. 28; Rodríguez-Díaz, p. 30; and Dzau et al., p. 32.

The year 2017 has seen a devastating series of hurricanes across the Caribbean, Central America, and the United States—Harvey in August, Irma and Maria in September, and Nate in October. The first three caused devastation along their paths and reached the United States as Category 4 hurricanes.

Inevitably, there has been discussion on the role of climate change in increasing the severity of tropical storms generally and this series of hurricanes specifically.

We address the causal attribution of severe and extreme weather events to climate change and the associated health consequences. This attribution is of primary scientific interest but comes with evident political implications.

CAUSAL ATTRIBUTION OF EXTREME WEATHER EVENTS

The broad community of atmospheric scientists has brought increasing attention to the causal attribution of extreme weather events to human activities.[1] The underlying approaches will be

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familiar to those knowledgeable about causal attribution in public health, particularly the adoption of the potential outcomes framework, which compares what is observed with what is expected under an alternative scenario of no exposure to the factor of interest. This hypothetical state of no (or an alternative to reality) exposure is referred to as the *counterfactual*, that is, counter to the facts.[2]

An analogy in public health is the comparison of lung cancer risk in smokers to the counterfactual risk that smokers would have had as never smokers. In the attribution of weather events to climate change, different counterfactuals are relevant to different questions. One example is the current climate, as it is affected by human activities, compared with past climate conditions. Another is the comparison of "business as usual" scenarios—that is, continuing on the present trajectory of increasing emissions of greenhouse gases—with alternative futures in which emissions plateau and then decline.

FREQUENCY AND SEVERITY OF STORMS

In approaching the attribution of storms and other extreme weather events to climate change, atmospheric scientists estimate probabilities of causation, a notion familiar to public health scientists. For example, we generally accept that it is not possible to determine whether smoking caused a particular case of lung cancer, but we do know that the odds of this being the case are very high (about 8:1 in an American male lifetime cigarette smoker). On this basis, we can estimate the likelihood that the particular case resulted from smoking and hence the population-wide benefits of reducing or eliminating altogether tobacco smoking. Climate scientists have adopted this approach and emphasize that the question is not "Did climate change cause event X?" but "By how much did climate change increase the chance that event X would occur?"[3]

The approach taken for this estimation is parallel to that used in epidemiology to estimate the attributable risk in those exposed to a factor (i.e., the attributable risk in exposed = $(P_E - P_0)/P_E$, where P_E is the probability of the outcome in those exposed and P_0 is the probability in the unexposed). For hurricanes and climate change, P_E could be the probability of more or of more severe hurricanes in the setting of climate change, and P_0 is the probability associated with the counterfactual scenario.

ATTRIBUTION AND LIABILITY

In public health, attribution and liability are closely linked and form a basis for policy action and, in some instances, compensation. In some legal settings, proof of causation is judged on the basis of "more likely than not," meaning that the outcome rests on establishing the presence of exposure because of a relative risk greater than 2. Climate scientists have put their toes into the same water, for example, in exploring the issue of responsibility for extreme events such as the 2003 European heatwave.[1]

The attribution of events such as Harvey and Irma is more difficult than is attribution in the lung cancer example because of the difference between climate and weather. Exposure estimates (analogous to the presence or absence of smoking) relate to climate—what prevails in the long run—but the outcomes are acute weather events, and these are qualitatively different phenomena. The relation between weather and climate is complex, and modeling different counterfactuals (e.g., storm frequency in a world without human-induced climate change) is not straightforward.

Precipitation is especially difficult to simulate, because it depends on much tighter space and time scales than apply to temperature and is heavily influenced by local physical processes such as convection.[4] Nonetheless, such modeling is difficult but not impossible; climate models are now capable of simulating the incidence and intensity of tropical cyclones, with and without greenhouse loading, and distinguishing to some extent the influences of natural variability (such as the occurrence of El Nino events) from anthropogenic forcing.

A recent modeling study of this kind examined cyclone activity in the western north Pacific area in 2015 and linked the extreme energy levels that were observed to human-induced climate change. This and other studies have concluded that climate change makes high-intensity storms more likely, but it is less certain that the overall frequency of storms is affected.[5]

ATTRIBUTING HEALTH IMPACTS

Attributing health impacts is even more complex than is attributing weather events, because many variables are relevant aside from the meteorological conditions.[6] There is no single method for this task. If there were sufficient data, it might be possible to proceed in steps, determining first, for example, whether a rise in greenhouse gas emissions increased the probability of very high temperatures and, second, to what extent excess mortality may be attributed to observed high temperatures. Other health outcomes, such as geographic spread of vector-borne disease and water-borne infections in warming seas, may require different analytic approaches, including pattern matching and argument from understanding disease mechanisms.[7]

For hurricanes, modeling health impacts is challenging because the impacts of storms are modified strongly by local circumstances. The health losses that result from the storms can be attributed, in part, to the lack of effective and general adaptation to extreme weather. In Houston, Texas, for instance, there were features of the city, such as urban expansion over wetlands and a landscape dominated by impervious surfaces, that made the flooding worse than it would have been otherwise.

Despite these complexities, the recent storms provide a powerful reminder, absent modeling, that hurricanes directly and indirectly increase mortality and lead to long-term increases in morbidity. Media accounts document many deaths from physical injury and drowning: access to clean water has been interrupted for millions as has the availability of electric power; elderly nursing home residents died in Florida from heat exposure; and needed and life-sustaining medical services were lost by many because hospitals closed and dialysis units could not operate. For the longer term, people face loss of property, water-damaged homes, and loss of livelihood, and there may be persisting economic and psychosocial consequences. Puerto Rico seems at particular risk in this regard.

The hurricanes of 2017 are consistent with model-based projections of more severe weather associated with climate change. The resulting devastation has reached broadly; Puerto Rico and other Caribbean islands will need years to recover. These storms offer another moment to begin to address climate change and its implications, yet the Environmental Protection Agency administrator Scott Pruitt has said that it would be "too insensitive" to have that discussion now. The storms' victims may wish that action had been taken decades ago. AJPH

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